

PEDESTAL CRATERS AT HIGH LATITUDES ON MARS: MARGINAL SUBLIMATION PITS IMPLICATE ICE AND SNOW IN PEDESTAL CRATER SUBSTRATE. S. J. Kadish¹, J. W. Head¹, N. G. Barlow², and D. R. Marchant³. ¹Department of Geological Sciences, Brown University, Providence, RI 02912 USA (Seth_Kadish@Brown.edu), ²Dept. Physics and Astronomy, Northern Arizona University, NAU Box 6010, Flagstaff, AZ 86011, ³Dept. Earth Sciences, Boston Univ. Boston, MA 02215.

Introduction: Pedestal craters (Pd) (Figs. 1-3) are a subclass of impact craters on Mars [1] characterized by a crater perched near the center of a pedestal (mesa or plateau) that is surrounded by an often-circular, outward-facing scarp; the scarp is typically several crater diameters from the rim crest (Figs. 2-3), and tens to over 100 meters above the surrounding plains (Fig. 2). Pd have been interpreted to form by armoring of the substrate during the impact event, usually by an ejecta covering [e.g., 3], increased ejecta mobilization caused by volatile substrates [4], distal impact-melt-rich veneers [5], and/or an atmospheric blast/thermal effect [6]. Following armoring, a marginal scarp is created by preferential erosion of the substrate surrounding the armored region, most commonly thought to involve eolian removal of fine-grained, non-armored material [e.g., 3]. The preferential distribution of Pd at latitudes above about 40° [7-9] (e.g., Fig. 3), together with an increased understanding of the role of redistribution of ice and dust during periods of climate change [e.g., 10-11] have led many researchers to suspect that the substrate might have been volatile-rich [8-9, 12-14]. Specifically, some [e.g., 8-9] have called on models of impact into volatile-rich targets to produce Pd during times of higher obliquity, when mid- to high-latitude substrates were characterized by thick deposits of snow and ice [e.g., 15], and sublimation of a thick regional volatile unit, except below the protective cover of pedestal craters. Thus, this model predicts that thick deposits of snow and ice should underlie Pd, while the eolian model [3] calls for primarily deflation of sand and dust. Elsewhere we report on the results of a study to document and characterize 2422 pedestal craters on Mars equatorward of ~60° N and S latitude [16] in order to test these hypotheses for the origin of pedestal craters. Here we report on the detection of features interpreted as sublimation pits in the scarps surrounding a class of pedestal craters in Utopia Planitia. We interpret these to mean that this class of Pd is underlain by ice and snow deposits.

Marginal Pits in Pedestal Craters: Pedestal craters with marginal pits are a newly identified crater morphology in which numerous pits occur along or outline the marginal scarp of a pedestal crater (Figs. 2-3). The crater ejecta deposit surface (top of the Pd) is perched several tens of meters (up to about 100 m) above the surrounding terrain, similar to a typical Pd crater (see profiles in Fig. 2). At the Pd plateau edge, the marginal scarp slopes down to the surrounding terrain, except where it is interrupted by a pit. The pits have a typical depth of ~20 m and are often best developed along the pole-facing and equator-facing direction of the scarp (Fig. 2 and 3; left), although coalesced scarps can extend around a significant part of the scarp circumference (Fig. 3; right). Pits are elongated (Fig 2), often appear to coalesce to form larger pits (Fig 2, 3), and can form a marginal depression near the base of the scarp along a significant part of the pedestal circumference (Fig 3; right). Altimetry indicates that pits form in the side of the pedestal scarp, rather than extending down into the surrounding substrate (profiles in Fig. 2). Pd craters containing scarp pits identified thus far are small (D <5km) and occur

poleward of 50°N, between ~80°E and 160°E in Utopia Planitia (red dots in Fig. 1). Pits are characterized by relatively steep margins and cusped shapes. Pits are similar in morphology to dissected terrain [11,17] and pits on the floors of some ancient outflow channels [18], both thought to represent sublimation of an ice-rich substrate. They are also similar to formerly ice-rich and now beheaded pits in the proximal part of debris-covered glaciers on Earth [19] and Mars [20] (see also [21]).

Discussion and Conclusions: The similarity of the marginal Pd crater pits to ice sublimation pits leads us to favor an origin through sublimation of ice and snow, exposed along the scarp at the edge of the Pd. In this interpretation, an impact crater forms in a thick (~10s to ~100 m) regional high-latitude deposit of ice and snow, mixed with dust. The area around the crater (the future top of the pedestal) is preferentially armored by proximal ejecta and distal sintering effects of impact melt and atmospheric blast/thermal effects accompanying crater formation [5-6]. At some time following crater formation, obliquity-driven climate change removes the intervening snow and ice, leaving the pedestal crater. The volatile-rich scarp margins undergo continued sublimation to produce the pits. The Pd with pitted margins in Utopia are somewhat larger than other Pd, and we interpret this to be the reason why pits are so well displayed there. Ice-rich layered substrates are thus interpreted to underlie other Pd (Fig. 2).

Pd are therefore interpreted to represent the remnants of a once much more extensive layered, climate-related deposit, similar to, but much thicker than the layered latitude-dependent mantle emplaced in a recent ice age [11,17]. On the basis of the large number and widespread nature of the Pd craters (Fig. 2) [16], we interpret this climate-related deposit to have persisted for a significant part of the recent past, implying that obliquity was relatively higher than at present during a significant part of the Amazonian period of the history of Mars. These craters are excellent candidates for exploration and analysis by the SHARAD radar instrument [22].

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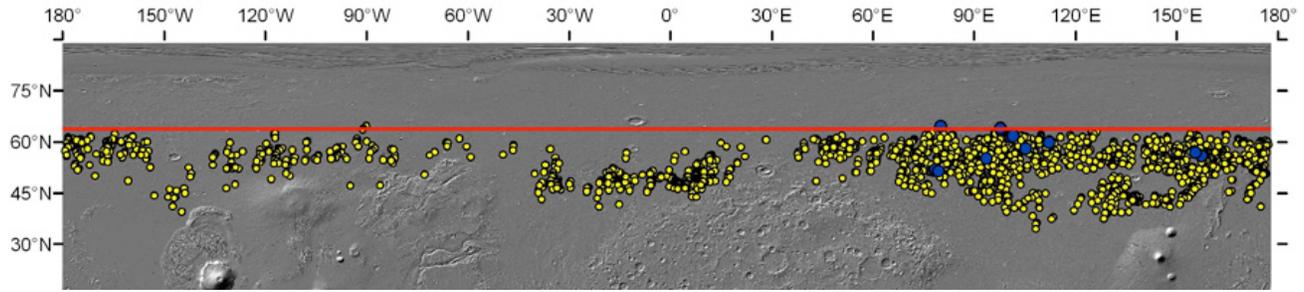


Fig. 1. Distribution of Pd craters (yellow dots) from 60°N to 15°N, and pitted-margin craters in Utopia Planitia (blue dots).

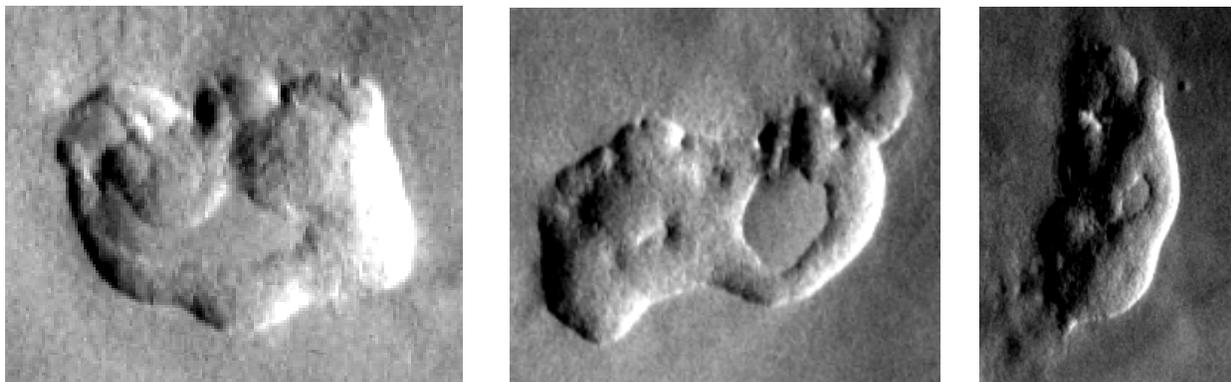
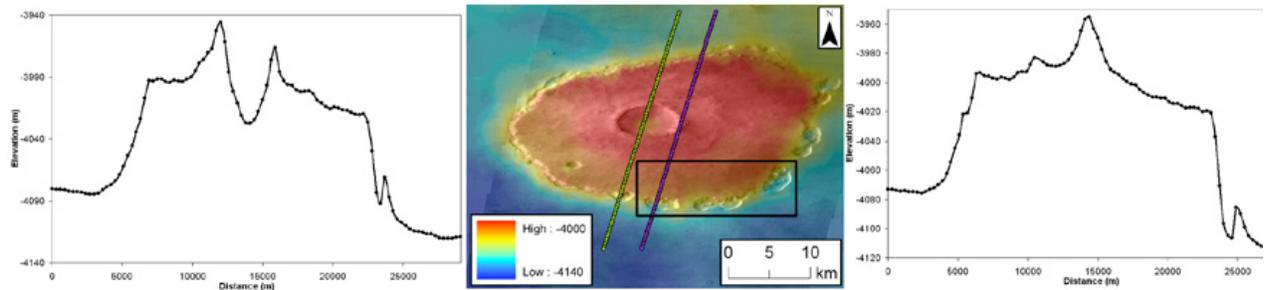


Fig. 2. A pedestal crater with scarp pits: THEMIS VIS V13602003 on MOLA topography (upper center) showing MOLA profiles; left is western track. The profiles resemble typical Pd craters in cross-section, with the addition of the scarp pits seen on the right side of each. Enlarged views of pits (location within black box, from left to right). One profile (upper right) crosses pit (lower left). Bottom: pit long axes = ~2.2, 3.2 and 3.7 km.

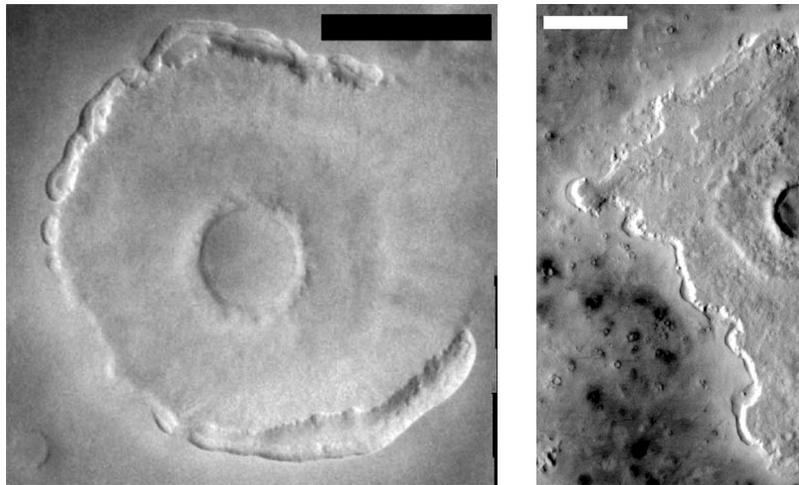


Fig. 3. Pedestal craters with extensive scarp pits: Left, THEMIS V10457014, showing some irregular and elongate pits, and coalescence of pits along the southern boundary into a pit extending along more than 1/5 of the Pd circumference. Pits occur preferentially on N and S-facing pit margins. Right, THEMIS image showing elongate pit with a very sinuous, west-facing margin. Scale bars for both images are 5 km.